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**Network Computer Technology
Phase I: Viability and Promise within NASA's Desktop
Computing Environment**

Peter Paluzzi, Rosalind Miller, West Kurihara, and Megan Eskey

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Network Computer Technology

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Summary

Over the past several months, major industry vendors have made a business case for the network computer as a win-win solution toward lowering total cost of ownership. This report provides results from Phase I of the Ames Research Center network computer evaluation project. It identifies factors to be considered for determining cost of ownership; further, it examines where, when, and how network computer technology might fit in NASA's desktop computing architecture.

Executive Summary

CIO Vision—Doing More for Less

NASA, like other government agencies and industry, is being compelled to find more effective ways of doing business which will enable the agency to do more for less—faster, cheaper, better. In a period of downsizing and declining budgets, NASA must partner with industry to achieve ways of accomplishing its ever-increasing mission with less resources, a fact especially true in the case of information technology.

To respond in part to the question of how NASA can do more for less while enhancing productivity, the Ames Research Center Chief Information Officer (ARC CIO) established the Network Computer Technology Evaluation Team. The role of the team is to partner with industry and evaluate for NASA the benefits and future implication of emerging network computer technology (NCT) to NASA. This report summarizes the team's views and findings regarding NCT during Phase I of the evaluation.

Network Computer Technology and the CIO Vision

The most visible and significant component of NCT is the network computers themselves. Network computers (NCs) are information appliances that provide basic desktop functions which include, but are not limited to, e-mail, spreadsheet, word processing, calendaring, presentation, data entry, point of transactions/point of

sales, and World Wide Web browsing. Typically, NCs have a display, keyboard, system unit, and network connection, but no hard disk or floppy drive. Because NCs typically have no local disk or persistent storage, they rely on a server system to provide access to applications, data, and documents.

NCs and NCT address the CIO Vision of doing more with less by seeking improvements in end-user productivity while reducing capital, maintenance, and support costs. End-user productivity has always been an issue in enterprise computing. In the days of timesharing, users shared a host mainframe computer with character based terminals. Communication and interaction between users was good, but the functionality of the terminals was limited compared to the displays of today. The performance of a single host architecture did not scale well with increasing numbers of users and thus imposed a cap on end-user productivity. However, end users did not have to be concerned with tasks such as application maintenance and backup of their data.

The introduction of personal computers (PCs) sought to break free from the bottlenecks of a single shared host and provide greater functionality. Only one person used the PC at a time and there was no competition for resources such as machine cycles and storage. As a result, there was an immediate perception of improved productivity because of the increased responsiveness of the system. On the other hand, these desktop computers were not normally interconnected, and communication and data exchange between users flagged. PCs also required a significant amount of "care and feeding" on the part of end users. Later, the PCs increasingly became networked, but still largely remained "mini-mainframe islands."

NCT aims to continue the delivery of better functionality and responsiveness to the end user while retaining the inherent system administration "best practices" of host based computing. User interaction and display operations take place on the NC. Application management, system administration, and some computational tasks take place in the more easily controlled and

maintained environment of the centralized server. Other duties such as access control, configuration management, security and integrity, interoperability, and system reliability are also better executed from a central server by qualified support staff. Consequently, end users can spend less time doing these things and more time being productive at their jobs.

In addition to productivity improvement, NCs have the potential of achieving operational cost savings over PCs. Industry studies indicate projected cost savings of between 26% and 39% per unit. These savings are in lower costs for initial hardware procurement, software, technical support, and systems administration as well as end-user operation. However, it is not clear that these studies have taken into account factors relevant to the NASA environment. Network and server impact is an example of such a factor. Also, current NASA data do not include cost components for end-user operation. Such differences have further complicated comparisons and determination of total cost of ownership (TCO) benefits.

There are special considerations that will affect the deployment of NCT. The local area networks and existing servers will need adequate capacity to accommodate any increase in demand for network bandwidth and processor availability. In addition to having enough capacity, the network and server architecture that supports NCs must be robust and reliable. If users are to depend on NC devices for their general computing and communication needs, then the resources on the servers must be available on demand 24 hours a day, 7 days a week. Steps will be needed to ensure rollover to backup systems in the event of a failure in any critical component.

Deployment of NCs may, in fact, result in startup costs associated with migration and infrastructure upgrades. While some engineering models seek to project this impact, all make simplifying assumptions that may make them less relevant to the NASA environment. In order to get a better picture of how NCs will affect the NASA information technology (IT) infrastructure, better performance metrics are needed that take into account the local system and network architectures as well as the mix of applications used. These metrics can be developed through a limited deployment of NCs throughout the enterprise. A limited NC deployment is planned for Ames Research Center during Phase II of the NCT evaluation.

Another consideration for deployment is the cost for training system administrators, technical support staff, and users during and after a migration to NCs. The

extent of this training or retraining depends on the NC architecture used and the applications to be supported.

Perhaps the foremost issue affecting the success of NCT in the enterprise is the availability of applications for NCs. The first NCs were mostly display terminals that relied on the server to execute and store the application. The early acceptance of these devices rested on their ability to access existing applications such as office productivity suites—the disadvantage being that users must share the computational capacity of the server.

The next wave of NCs will support direct execution of Java applications which are downloaded from the server. Users of these NCs will not have to share the computational load of the server. However, until now there has not been a viable Java based office productivity suite. Nevertheless, the future is encouraging and vendors are expected to release these products during the first and second quarters of calendar year 1998.

Java is key to achieving the greatest advantage of the NC. The largest cost savings cited by the industry studies are for those NC systems which rely on client-side execution of Java applications. These Java applications are developed from software elements called "classes" that are dynamically loaded as needed. Within this architecture, updates to software can be done at any time, often without notice by the user. Moreover, deployment of applications and maintenance of consistent versions across all platforms become automatic.

Java's "write once, run anywhere" design goal means that only one version of an application is needed for all ranges and makes of computers. Further, the Java security model provides a starting point for implementing security policies in the NC environment. Many of the acknowledged systems administration best practices are already implemented as part of the Java computing platform.

The differences seen between NC architectures and their rapid evolution suggest that there is no "one size fits all" NC solution today. NCs do not yet provide the high-end multimedia capability of more expensive PCs. However, it is expected that NCs will be able to offer the core productivity tools which are necessary for organizations to operate. While NCs cannot currently replace scientific and engineering workstations, they can reduce the requirement of having a second system to provide those basic desktop functions. However, further tests conducted by the U.S. Navy (Naval Command, Control and Ocean Surveillance Center)

may indicate some progress in areas such as information display and command and control.

Over the next six months to a year, many advances are expected in performance and capability of NCs as well as the emergence of new Java based applications which will encourage a reexamination of current notions of enterprise computing. It has been customary

to focus on the metaphor of the desktop. The emergence of NCs and NCT requires looking outside the "box" of the desktop to consider general purpose computing in the context of a network of enterprise services delivered to the user in the same way documents and content are delivered by the web.

Technology Assessment and Issues

During the period from January to June 1997, the Blue team conducted an assessment of NCT using information collected from industry reports, vendor documents, interviews with experts, and tests performed in the Ames NCT laboratory. In the course of this work, the Blue team identified technology issues that have a bearing on deployment of NCT within NASA. These issues are:

- Maturity, development, and growth of NCT
- Costs and savings
- Productivity gains and management improvement
- Network and server impact
- Training and migration
- Matching NCT alternatives to target applications
- The need for better metrics
- The roles played by Java and legacy applications

The following is a discussion of the issues.

Maturity, Development, and Growth of NCT

NCT is a new technology. The systems available to the Blue team all were introduced or went to market within the last year. However, portions of the technology have been around for some time, as shown in table 1.

The NC-S systems are based upon X-terminal technology which appeared in the late eighties and early nineties. NC-S systems still support X-terminal technology today as well as the newer intelligent

content architecture (ICA) protocol that improves performance over low speed network connections. At the same time, the web project was getting under way at CERN (the European Laboratory for Particle Physics, Switzerland), and the Oak project began at Sun Microsystems, which ultimately led to Java. The National Center for Supercomputer Applications later introduced a graphically oriented tool known as Mosaic to browse the web. These technologies came together in 1994 with the creation of Java "applets" or programs loaded into web browsers using the Internet.

Not long after the public announcement of Java in the spring of 1995, Oracle made trade press headlines with its proposed diskless Java processor called the Network Computer. Oracle also announced that it had enlisted Apple, IBM, Netscape, Sun, and others as partners willing to build devices that adhere to the NC reference profile (NCRP). This was the beginning of the NC-C class of machines. Within a year and a half, most of the vendors who are participating in this evaluation announced their NC-C and NC-S systems. NCT consequently is based on mature technologies as old as TCP/IP and X-Windows. However, integration of the technologies that produced the NC is new. This presented some difficulties for the evaluation because key pieces of the technology were not in place during the evaluation period. For example, it was hard to do side-by-side comparisons of all NC categories. Not all the NC-S operating systems supported local Java execution and some NC-C devices did not have software for X-Windows and ICA protocols. Different protocols were also used among the NC vendors for booting the devices. This meant that there was very

Table 1. NCT historical timeline

1984	X-Windows
1989	X-terminals
October 1990	WWW project begins at CERN in Switzerland
January 1991	Sun begins the Oak project which later spawned Java
1993	Mosaic distributed by NCSA
1994	Citrix Winframe intelligent content architecture technology
May 1995	Java introduced by Sun
September 1995	NC concept introduced by Oracle
1996	NCD, HDS, and others announce NC-S class systems
February 1996	Sun announces Java based microprocessors
May 1996	Java based office suites, prototype NC-Cs demonstrated at JavaOne conference
October 1996	Java stations introduced by Sun
October 1996	NetPC concept announced by Microsoft
January 1997	Ames initiates NCT evaluation

limited interoperability between NCs and boot servers from different vendors. During the evaluation, NCs could not boot across subnet boundaries using dynamic assignment of IP addresses. More importantly, the number of Java enterprise applications was small compared to those currently available for UNIX and Microsoft Windows operating systems. Nevertheless, NCT is developing and growing rapidly.

Table 2 gives an indication of the timeline for predicted NCT developments and enhancements. Many of the problems listed above were expected to be addressed within a year. NC-C systems such as the Sun JavaStation were expected to be able to boot across subnets by fall 1997. First customer shipments of Java based office application suites may be occurring by the end of the first quarter of calendar year 1998. Microsoft has also announced multi-user session support for Windows NT 4.0. Faster processors for all the NC systems will be available by January 1998.

Other developments such as the availability of Java based office suites are expected to occur by the spring of calendar year 1998. During this time, there will also be several enhancements to the Java Runtime environment and associated packages. New visually oriented development environments such as Sun's Project Studio and IBM's Visual Age for Java will make it easier for application developers to create programs for the NCs. Despite the relative youth of NCT, the pace

of growth in terms of numbers and functionality is increasing rapidly. It is highly likely that within the next year or two the capabilities and usage of NCs will expand beyond call centers, point of sales, and kiosks to office desktops and general purpose computing.

Costs and Savings

Initial Capital Costs

Much of the NC news in the trade press also emphasizes the initial NC hardware cost savings in addition to TCO. While reports of \$300 and \$500 NCs make for eye-catching headlines, costs for all of the NCs installed in the NCT laboratory range from around \$600 to \$1500. The approximate costs of NCs in each category are shown in table 3.

NCs are approximately only half the cost of a typical new PC or Macintosh. However, trends in the industry suggest that the prices of PCs are dropping. For example, within the last year PC manufacturers have attempted to meet NC competition by introducing "cheap PCs" which cost in the neighborhood of \$800 without the monitor. The last entry in table 3 shows the projected cost of converting an existing PC or Macintosh to an NC-C by installing an appropriate Java enabled browser. Sun is also intending to release their NC-C operating system, JavaOS, for older Intel 486 machines in order to convert them to NC-Cs.

Table 2. Projected NC developments

Fall 1997	Cache storage in some NC-C systems
Winter 1997-1998	4x to 5x processor speedup Introduction of 100BaseT network support NC-S systems get local Java execution Full CD quality audio output, audio input
Spring 1998	First customer shipments of Java based office suites First shipments of Java based office suites prototypes, NetPCs Bootling of NC-C system across subnets, boot from multiple vendor hosts
Fall 1998	SmartCard and public key encryption available to customers

Table 3. Comparison of initial hardware purchase costs

System type	Cost of system unit*	Monitor	Other**	Total
PC or Macintosh	\$2436	\$765	\$0	\$3201
NC-S	670	765	0	1435
NC-C	742	765	0	1507
NetPC	1000	765	0	1765
Existing desktop	0	0	300	300

*Ames GMR contract prices are shown for PC or Macintosh. The NetPC cost is an estimate based on published reports.

**For existing desktops, the cost shown is for software that converts the system into an NC-C.

The reason NCs cost less to buy than "traditional" PCs is because of their reduced functionality (i.e., the hardware they don't have, such as hard disks, floppy drives, etc.). There are cost factors other than acquisition of the NCs themselves. Depending on the enterprise IT infrastructure, networks and servers may need to be upgraded. Also, there are costs associated with migration of the support staff and users. These issues are addressed later in this report.

Total Cost of Ownership

The issue of TCO gets most of the attention with regard to NCs. TCO is the annual cost of operating and maintaining a desktop system. The Gartner Group (ref. 1) has done several studies on TCO, and their figures are often quoted. The cost components of the Gartner TCO model are capital, technical support, administration, end-user operations, and local area network (LAN). Table 4 summarizes the Gartner Group TCO components as life cycle costs for one year.

Capital. The description of the hardware client capital costs was given in the preceding section. Other capital costs include that of the operating system software and applications software. There may be savings for software costs if better site licenses and right-to-copy terms are negotiated with the vendor. While these costs would be incurred for either NCs or PCs, there are potential additional savings from vendors of Java applications because of lower development costs and elimination of platform specific versions.

Technical Support. The cost of providing help to users has been projected by industry accounts to be less for

the NCs. The rationale behind this is that having fewer functions leads to fewer problems and difficulties. Also the use of simpler applications written in Java may lead to fewer trouble calls. Furthermore, many of the NC attributes which give way to a single point of control may contribute toward lessening the need for technical support. This is an area of speculation until measurements can be made in a later phase when NCs are actually deployed to users as desktop replacements.

Administration. Cost savings in ongoing administration of existing desktop systems have already received considerable attention. Recent NASA studies have shown that consolidation of desktop services will lead to reduced operating costs. The resulting post consolidation per seat costs for system administration are in the range of \$1100 to \$1300 for PC/Mac for traditional desktop systems (ref. 2). The Gartner study asserts that such costs can be further reduced 20% to 25% by enforcing system administration best practices. In a recent Datamation article (ref. 3), some of these best practices were identified as:

- Standardized hardware and software
- Central software distribution and management
- Asset-management programs
- Deployment of desktop management suites
- Improved training programs

Additionally, other second-level best practices, such as similar and consistent file systems, also make for easier administration.

Table 4. Gartner Group TCO components (life cycle costs for one year)

One time and annual costs (first year)	Win95 PC	NC-C	NC-S	NetPC/NT 5.0
Capital (one time)	\$1850	\$980	\$1015	\$1733
Technical support	1066	870	859	970
Administration	945	440	460	422
End-user operations	3464	1799	2219	2073
Desktop costs	7325	4089	4553	5198
Network capital (one time)	682	689	882	664
Network technical support	638	611	638	567
Network administration	552	230	310	406
Network end user	588	392	392	434
Network costs	2460	1922	2222	2071
Total costs	\$9785	\$6011	\$6775	\$7269
Reductions (Win95 base)		39%	31%	26%

Source: Adapted from Gartner Group and Datamation.

The problems with exploiting best practices in a research environment include (1) the diversity of systems and platforms needed to support widely differing requirements and (2) the resistance to change. Migration to best practices in such an environment depends on establishing standards which will be valid across the range of platform types. Also needed is the willingness on the part of users to change system management methods. Experience has shown that the migration to best practices has not been overwhelmingly popular. For these reasons, it is difficult to project the cost of migration to best practices in a diverse computing environment. However, NCs can potentially provide an alternate approach toward the benefits of best practices.

Many best practices are built into the NC architecture. It is easier to have standard hardware configurations because NCs have limited options and bear similarities to one another. By putting the applications that NCs use on the server, it is straightforward to standardize software. Server repositories for NC software by default centralize software distribution and management. With NCs, the emphasis for asset management and desktop management suites is also shifted to the server.

It is projected that after the switch to NC-C systems some enterprises will be able double the number of desktop systems maintained by a single system administrator.

According to the Ames Research Center Desktop Systems Management Consolidation study, current estimates of the number of systems maintained by a system administrator are 30 for UNIX workstations, 90 for Macintoshes, and 75 for PCs. If the degree of improvement is consistent for NC adoption, a NASA system administrator could be managing at least 150 NCs.

End-User Operations. As can be seen in table 4, end-user operations account for a sizable amount of the total costs in the Gartner model—26% to 35%. Equivalent data for Ames are not available and are difficult to project. However, using the Gartner numbers as a starting point, it may be reasonable to assume that end-user operations costs could drop 2% to 9% with NCT.

Network Costs. According to Gartner Group estimates, the effect NCT will have on network costs is noticeable but not significant. In addition, the Gartner numbers show that the network costs are only about one half of the desktop costs. This suggests that any network cost improvements will have only a small effect on the overall total cost.

Productivity Gains and Management Improvement

A study of Forbes 100 IT managers regarding NCT was done in 1997 by the Yankee Group. The results show that there is greater importance placed on other issues than TCO. In fact, TCO ranked fifth after centralized management, unifying software platform, central storage, and lower initial price. These issues are associated more with maintaining or improving productivity and gaining greater control over the enterprise's resources.

Centralized Management

One of the perceived problems associated with individually operated and maintained enterprise desktops is the difficulty in controlling or managing this resource to ensure productivity. Experience has shown that aspects of control affecting productivity include:

- Access
- Configuration
- Security and integrity
- Application software
- Interoperability
- Reliability

Access. Unless otherwise configured, many desktop systems are "open" and, as such, accessible to anyone. On the other hand, it is common for staff to go from one desktop to another and yet still expect to access their own computing environment. This notion of a network identity is not often implemented with PCs, although a form of it has existed for years with UNIX systems.

Both the NC-S and NC-C systems depend on a server authenticated login. Since the user's identity is managed on the server, users can migrate from one NC to another and still establish their own session from the selected server. All of the NC systems tested in the NCT laboratory required some sort of user id and password before establishing a session. The NC-S systems ask the user to select the server prior to login. Once selected, a login screen from the server is displayed. The NC-C systems are by default connected to a particular boot server which presents a user id and password query panel after power-up. The notion of network identity with the NC-C systems is currently managed by a Sun product called NIS. While a related product, NIS+, may be acceptable in the existing enterprise security framework, NIS is not, owing to

security concerns. It is understood that other alternatives to NIS are being considered by the NC-C vendors.

The SmartCard is another form of access control currently under development by NC vendors. SmartCard readers will be available in some NCs. A SmartCard contains a small embedded processor and memory, which in turn holds an individual's identity information, encrypted keys, and computing environment profile. With a SmartCard, users can take their environment with them and securely access those parts of the enterprise computing system for which they are authorized. NC vendors are also predicting that SmartCard-enabled NCs will be located in public places such as airports and hotels. Pending universal adoption of SmartCard standards, a person could travel with only a SmartCard and not carry a laptop computer. Upon inserting the SmartCard into, say, an airport lobby NC, travelers could establish their own desktop environment and securely perform tasks such as e-mail or document processing. Some NC vendors such as Network Computer, Inc. (NCI) have based their entire offering on SmartCard authentication.

Configuration. Productivity losses can arise from the diversity of system configurations within an enterprise, even if all systems are the same kind. Systems support staff indicate that the variations of system options—peripherals, installed software, and file system configurations—make their work more difficult and time consuming. The NCs provided for this evaluation all limit the hardware and software options and functions. The NCs have the features that most users will need (such as mouse, audio, printer port, and serial port), and some even have a PC manufacturer interface adaptor (PCMIA) slot. Few of the NCs tested had a local hard disk. The HDS Supra did have a floppy drive as an external accessory and an optional PCMIA local hard drive for local booting. The NC-S systems also had nonvolatile read only memory for network boot parameters.

Security and Integrity. A hostile attack on a conventional desktop system can be costly not only for the potential loss of data and confidentiality, but also for staff productivity which will be lost in trying to recover from the damage. Such attacks often occur when a virus is introduced from a download or from a floppy disk. The attack may read sensitive data from the desktop hard drive or, even worse, erase its contents. Without a local hard disk, NCs appear to be relatively immune to virus attacks. It is expected that security and integrity of NCs will be a function of the security measures and policies in place on the servers and throughout the enterprise network.

Application Software. The enterprise's application software must be available on demand to all workers who need to use it. Ordinarily this software must be installed on each desktop system. Version upgrades are a problem in large enterprises owing to the time needed for installation on all systems. This approach to promulgating software and upgrades takes time on the part of system administrators and adversely affects user productivity. Staff cannot access the system while software is being installed. The NCs bypass local installation either by running the application on the server (NC-S case) or by downloading the software on demand (NC-C case).

Interoperability. Systems must be able to communicate and share data with one another. If they cannot, time can be lost in finding alternative ways to move data between systems. The extreme case is when data are manually transcribed. Through the use of servers, NCs appear to go a long way toward achieving interoperability. System administrators can ensure that server based applications do interoperate and that documents and data produced by one user can be read by another.

Reliability. Desktop systems which are unreliable and do not perform as needed have a serious impact on productivity. When systems do fail, repair should be quick in order to minimize disruption. During the evaluation period, none of the NCs ceased to work owing to a breakdown. However, installation was simple—only five cable connections were needed before power-on—and it would have been easy to replace the entire system unit with a spare and return it to a repair facility. No applications or data would be lost since they are stored on the server. The reduced functionality and number of options for NCs also means that there are fewer components to fail.

However, there are some reliability concerns for using NCs. These concerns involve dependence of NCs on the network and server systems, which is analogous to desktop telephones and the phone company network. If the network goes down, telephones are useless. Nevertheless, like telephone companies, IT operations have learned how to build fail-safe networks and redundant servers that can survive most system failures.

Unifying Software Platform

The motivation behind having a unifying software platform is to be able to run the same software on systems large and small as well as systems with different architectures. The productivity savings then come from reduced duplication of effort, which comes

about in two ways: less time is spent maintaining an application if there are fewer versions of it in use, and less time is spent by users in learning and operating key enterprise software if it operates similarly regardless of where it is run.

The NCs examined in this study seek to provide such a unifying software platform. NC-S devices allow access to legacy applications as well as newer tools. One version of the software resides on the server where it executes. It has the same look and feel on every NC-S device. The NC-C devices load the components of an application from a master copy on the server. Although an application executes on local NCs, it is the same application for all NCs. Furthermore, since the NC-C devices run Java programs, there needs to be only one version of the code for all platforms—the NC-S, NC-C, and existing desktop systems all have the ability to run Java programs if the Java Runtime environment is available on that system.

Centrally Managed Storage

Management of storage with conventional desktop PCs is commonly the responsibility of the user. Keeping applications current, organizing and accessing documents, and backing up data are some of the tasks which depend on due diligence on the part of the users. While the costs for accidental loss of key applications may be limited to time, the loss of documents or data can be of greater consequence. One of the attractions seen for NCT is the centralization of user application and file storage on systems that are meticulously maintained and backed up routinely. With central storage, it is easier (and more likely) to recover from a disaster when the proper procedures are performed by trained system administration staff.

Network and Server Impact

Incorporation of NCT within an enterprise will have an impact on the existing network and server architecture. Both the NC-S and NC-C architectures will place bandwidth demands on the network as well as impose greater workloads on the part of servers.

The network and server play essential roles in either of the NC architectures. Network and server reliability is critical. Applications usage patterns will probably require some reengineering of server connections to provide greater peak throughput, and server capability may need enhancement. Follow-on testing phases of this project will test typical configurations and applications usage to contrast and compare to classical usage.

Network Impact. The way NC-S and NC-C systems use the network differs. While NC-S systems do not require application software to be downloaded from the server, they do need to have constant interaction over the network to update their displays and transmit user input. Using X-Windows protocols, approximately 15 to 30 users can be handled over an ethernet segment. Switched ethernet can accommodate 100 to 200 similar NC-S systems (ref. 4). Greater network throughput is possible with NC-S systems that employ ICA protocol. However, there are greater processing demands for NC-S and server systems with ICA.

NC-C systems, unlike NC-S systems, execute applications locally rather than on a remote host server. These applications, which exist as collections of Java classes, are loaded on demand over the network. Display updates and user input are handled locally on the NC-C system without accessing the server. This leads to network behavior which is more like web browsing. That is, there is not a steady stream of display images and graphical data but rather intermittent requests for web pages and software components. Using a model provided by Sun Microsystems (ref. 5), the level of network interaction is measured in HTTPOPS (HyperText transfer protocol operations per second). NC-C systems like the JavaStation exhibit about 1 HTTPOPS average with 10 HTTPOPS peak. The Sun model assumes an average of 10,000 bytes transferred per HTTPOPS. Using these figures and 30% TCP/IP overhead, roughly 20 NC-C users will saturate an ethernet segment. Using a switched ethernet will potentially support 5 to 10 times this number of users.

Tests conducted in the Ames NCT laboratory involved running a heavy database application (PowerSoft) on a 133 MHz Pentium system with four NC-S users on a dedicated 10BaseT ethernet segment. The heaviest network usage occurred when all systems initiated a boot sequence at the same time—approximately 36% of network capacity. The sustained network load throughout the rest of the test was roughly 4%. Similarly, the period of greatest network load for the NC-Cs was at boot time, when two NC-C systems consumed 36% of network capacity. However, network usage while running applications such as Java based word processing and spreadsheets programs was less than 4%.

In summary, NC-S and NC-S systems will apparently impose a similar load on the network yet with different sorts of network traffic. This traffic load is expected to vary, with the greatest network demands occurring during NC booting. While 20 or so users may comfortably share a network segment under normal working

conditions, there are likely to be delays if multiple users boot at the same time.

Server Impact. The extent of the server impact also differs for NC-S and NC-C systems. Because NC-S systems require applications to execute on the server, there must be enough processing, input/output, and storage capacity to accommodate multiple users. As an example, if 22 to 27 NC-S users need to access basic word processing, spreadsheet, and electronic mail applications, each with a performance level equivalent to a 75 mHz Intel Pentium processor, then a 200 mHz Pentium Pro uniprocessor is needed.

Increasing the number of processors on the server will support more users or more demanding applications. Between 4 and 8 MB of memory must be allocated to each user in addition to the memory occupied by the operating system and applications. Approximately 256 MB will be needed to support 22 to 27 NC-S users. Disk usage will vary greatly depending on the work being done. Enough disk space will be needed for the operating system, applications, page swapping, temporary scratch space, and user files. The computation of the amount of disk space, while enterprise dependent, should target having only 5 to 10 users per disk drive.

Just as NC-C systems look more like web browsers from a network standpoint, the NC-C server closely resembles web servers. Java classes reside on the server and are sent to the NC-C in much the same way as HTML (HyperText markup language) documents. The loads presented by NC-C systems on the server differ greatly, depending on usage patterns. The demands posed by NC-C booting and web access are the lowest, and middleware brokering of distributed computing (e.g., CORBA) are the greatest. If 1 HTTPOPS is assumed for normal NC-C activity, then a low-end system equivalent to a Netra j4 would be adequate for 20 users. Booting would result in 3 to 4 MB code image transfers but this would be sporadic, especially if the NC-Cs were never switched off. On the high end, a Netra j4000-4 would be needed to support 50 distributed computing NC-C users.

Training and Migration

Introducing NCT into the enterprise will require training on the part of users and support staff as well as creating migration issues. The amount of retraining will vary depending on the existing system environment in the enterprise. For example, users who already use Windows/NT and Windows applications will make the least change by migrating to NC-S systems and multi-

user Windows/NT servers. While there is more of a difference between the Windows and NC-C environments, the migration might not be as difficult as expected since the user interface is based on the familiar web browser model. System support staff will also need to be trained in server based NC administration.

Matching NCT Alternatives to Applications

NCT, at this time, is not a "one size fits all" proposition. The usefulness for scientific, engineering, and software development tasks is yet to be demonstrated and was not considered in this phase of the evaluation. The most likely target applications are:

- Point of transaction sites
- Data entry
- Clerical tasks
- General office computing (word processing, spreadsheet, and electronic mail)
- Web browsing and intranet

The NC-S systems form a bridge to legacy applications that can run on central servers. Enterprises which depend on such applications can use NC-S systems to achieve many of the benefits of NCT with minimal change to their user operations. This applies particularly to clerical tasks, general office computing, and web browsing. The NC-C systems today do not similarly support access to legacy applications. However, Java based software such as Lotus SmartSuite and Corel Office for Java will soon be available. Enterprises willing to develop Java software for point of transaction and data entry functions may consider the current NC-C systems as an alternative.

The Need for Better Metrics

Better metrics are needed to paint a clearer picture of how NCT can figure into NASA organizations and enterprises. Measurements for existing and NCT environments are needed especially in the following areas:

- System administration tasks
- Server loading under actual conditions
- Network performance under actual conditions
- End-user productivity and operations
- Hardware and software reliability and maintenance
- Functionality for a larger community of users

As discovered in the research of TCO, it is difficult to get a better understanding of costs because the industry research studies make assumptions and measurements which may not be appropriate for NASA. Examples include capital costs and end-user operations. It is proposed that Phase II of this evaluation focus on deploying NCs to staff and monitor the system performance, usage, and support costs as well as overall productivity.

The Roles Played by Java and Legacy Applications

Java is a key component of the NC-C systems architecture. The ability of dynamically loading Java programs as needed by an application running on an NC-C system is the basis of many of the features of this architecture.

Java is a general purpose computer programming language and a new approach for network centric computing. Java programs are essentially collections of classes which are called up for execution as needed. Classes are the patterns or "blueprints" used to construct the Java objects used in a Java program. Java classes can reside locally on a desktop system or remotely on an enterprise-wide server.

Much of Java's importance and appeal arises from its ability to reduce costs associated with enterprise application software. It is expected that Java will lead to lower costs for application software acquisition, deployment, and management.

Application software can be less expensive because Java developers can reduce their development time and expense. Java has features which promote good programming practices and improve programmer productivity.

Deployment of Java applications is potentially simple and inexpensive. The Java software components called classes can reside in "packages" stored on a centralized server. One copy of a Java class residing on a server can be accessed by and shared with all the Java enabled desktop client systems in the enterprise. Through this process, a user can fetch copies of Java classes on demand from the suite of Java packages currently installed. Consequently:

- The number of installations performed is reduced dramatically
- All desktop systems use the same version of an application
- Any updates of Java packages are immediately available to all desktop systems in the enterprise

- One copy of the application can be used on all systems and computer platforms which are Java enabled

Java provides an appealing solution for reducing the cost of managing applications. The computing architecture supported by Java offers the benefits of centralized software maintenance while taking advantage of computing cycles available on the NC-C system. Having one or a limited number of locations to keep applications means that less work is needed to:

- Limit the number of different application versions in use
- Give users timely access to software upgrades and patches
- Track software assets
- Reuse classes for in-house developed software
- Establish centralized management of software licenses

In addition, there are other collateral benefits of Java, such as the "sandbox" security model that is available in the Java Runtime environment. While users and system administrators should always remain vigilant regarding good security practices, applications written in Java need less attention to maintain a reasonable level of safety and security.

Java based applications require less system resources such as memory, a result of loading classes on demand and using "automatic garbage collection." The ability to run in "leaner" environments means that an enterprise can utilize desktop hardware which might otherwise be considered obsolete. The downside is that there is a dearth of enterprise-quality Java application software today.

Java developers are now acquiring the skills needed to produce robust applications. What this means is that to use the NC-C today an enterprise must be willing to use early Java software or internally develop the required code. This situation will remain until legacy applications are ported to Java or users migrate to current Java applications.

The NC-S systems play the role of bridging the gap between new and emerging Java applications and legacy code. This advantage will diminish with time because the NC-C systems will acquire the X-Windows and ICA protocols, developers will eventually port their applications to Java, and the NC-S systems will become more capable Java clients.

Appendix

NCT Evaluation Project

Background

The NCT Evaluation Project reflects the direction of the Ames Applied Information Technology Division in response to a request from the ARC CIO to evaluate for NASA the usefulness of NCT (e.g., NCs, NetPCs, Java) and its potential for improving productivity and reducing cost within the NASA desktop computing environment. The result of this evaluation will be a recommendation of an IT strategy for NCT.

A major core activity of the Division is new technology assessment and its infusion into the NASA workplace. In that role, the Division is identifying, evaluating, demonstrating (testbedding), and integrating promising technology to enhance workforce productivity. The Division serves as the model and showcase for the infusion of emerging technologies through the utilization of Ames IT research in partnership with the research efforts of industry and academia.

Rationale

The rationale for conducting this NCT evaluation centers around the fact that NASA organizations rely heavily on desktop PCs to perform daily mission-critical tasks. Oddly, the reliability of those systems may be a factor which adversely affects user productivity, resulting in the PC becoming a victim to its own success. For example, since the PC and its software have become more sophisticated and complex, system configurations can be easily altered by untrained users, resulting in downtime. Typical PC problems may take hours or even days for so-called experts to fix. Software packages often have new features which may not justify the time and expense of hardware upgrades, installation, and training. Word processors, spreadsheets, schedulers, and e-mail are all mission-critical productivity tools and therefore should be readily available and easy to use, which is sometimes not the case.

TCO studies show that typical desktop PCs cost between \$5000 and \$10,000 per year to maintain, with the cost constantly rising. An organization with 5000 PCs may incur annual costs of \$25M to \$50M per year (see table 4). It is clear that NASA must control these costs while still providing the tools necessary to perform the mission.

Project Management

The NC Blue team is a self-directed work team, formed in early November 1996. Individual team members were selected by the ARC CIO, from a skill mix of various specialized technical areas (e.g., technical consulting, advanced networking, IT planning, and management). The team has full responsibility for the planning, performance, and management of the evaluation. The team facilitates compliance and commitment to major project decisions, issues final decisions on project issues that cross organizational boundaries, and is accountable to the ARC CIO for work schedules, project costs, and achievement of project goals.

The team has responsibility for articulating Ames requirements and evaluation criteria for NCT and status report tracking. Further, the team has responsibility for the commitment of all resources required to conduct the evaluation.

Aside from the Blue and Red team members, the project is supported by a "cast of thousands." The cast includes the NC evaluation support staff, individuals (expert and non-expert) who, while not directly assigned to the project, act as consultants providing the following support:

- Systems Administration—Installation of NC server software, maintenance of user accounts, and monitoring of NC demands on server resources
- Network Administration—Provision of NC to server connectivity via the Ames LAN and monitoring of NC demands on the network
- Computer Security Administration—Review of NC security issues and security consultation
- Training Coordination—Provision of training of staff and volunteer testers on the NC and the NC base applications such as office suites
- Volunteer Testing—Usage of NC technology in addition to or in lieu of current tools with feedback on experiences. Initial volunteer testers will be a representative sample of the Ames resident staff in terms of technical abilities and job functions

Evaluation Project Approach

Phase I of the NC evaluation was limited to testing performed inside the laboratory area with technical users (system, database, and network administrators and security experts) performing functions on industry loaned NC equipment. In Phases II and III, the evaluation moves into a wider Ames community,

which will include nontechnical users (administrative managers, administrative support, non-IT researchers, and students) and organizations that have requested to become a part of the evaluation. NCs will be placed at the users' work sites to be used in lieu of their current tools with feedback on experiences.

Initial organizational meetings have begun to discuss a Java computing initiative. Industry partners from Sun Microsystems and JavaSoft have volunteered to provide support in this effort.

Solicited Industry Partners and NASA Customer Involvement

Throughout the NCT evaluation project, several combinations of industry partners and partnership arrangements were and are continuing to be developed. These partnerships have greatly facilitated this evaluation and, further, contribute significantly to Ames researchers' knowledge of other advancing technologies that can benefit NASA.

Initial vendor contacts began in late November 1996 with Oracle and NCI. In early March 1997, Sun Microsystems established a special NC support team tasked to work with five key government agencies. Ames was selected as one of the agencies to receive special attention and emphasis. By late May 1997, the Blue team and Division staff had seen product presentations from nearly all the major NC vendors and had populated the NCT laboratory area with loaned NCs from five major vendors (Sun, IBM, HDS, NCD, and Wyse). The NC Blue team used a variety of media types and forums to communicate the goals of the project to potential partners in private industry and to current and potential customers at NASA. The team hosted IT briefings and invited vendors to present

overviews of their current technology. Many of the initial partnerships were formed as an outgrowth of those meetings.

A web site was created, <http://mystic.arc.nasa.gov/nct/>, which describes the project in detail, and the URL was widely distributed to potential industry partners. Weekly team meetings were held which were open to NC evaluation industry partners. Further, the team spoke at a variety of systems administration Birds of a Feather meetings, and gave numerous tours of the NCT laboratory to upper management and staff.

To date, industry partners directly involved in this evaluation include HDS Network Systems, Inc.; Network Computing Devices, Inc.; Sun Microsystems, Inc.; IBM Corporation; and Wyse Technology, Inc. The team's longer term goals include forming alliances with NCI, a spin-off company of the Oracle Corporation, and one or more of the Intel based NetPC vendors, such as Compaq, Dell, or Hewlett-Packard. The support provided by the industry partners extends far beyond merely supplying equipment. Expert technical support has been included in all cases.

Established NCT Laboratory

The NCT laboratory was populated with nine loaned NCs from five major vendors (HDS, NCD, Sun, IBM, and Wyse). Two vendors (NCD and Sun) included boot servers with their NCs. The NC team provided an Intel based server and an IBM RS6000 server. The laboratory was configured on an isolated test subnet. One dedicated network monitoring system was added to the network, and the Intel server was configured with the Sun Microsystems network monitoring package for detailed network packet analysis. The laboratory network is shown in figure 1.

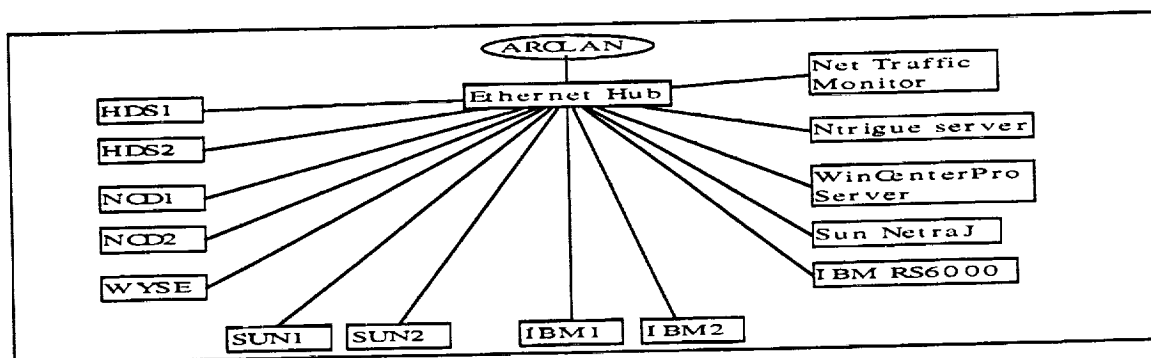


Figure 1. NCT laboratory network.

Conducted Tests

Phase I of the NC evaluation was limited to testing performed inside the laboratory area with technical users (system, database, and network administrators, and security experts) performing functions on industry loaned NC equipment. The findings are discussed in detail in the Technology Assessment and Issues section.

Functionality. The basic functionality the team looked for in the various NC architectures included the ability to run the standard office applications used throughout NASA (e.g., Word, Excel, and PowerPoint) and e-mail and web browser capability. During this initial phase of the evaluation, the lack of X-Windows and ICA protocol support for JavaStations left the team at a disadvantage for conducting an apples-to-apples comparison of operating scenarios.

Network and System Loads and Scaling. Tests were run to collect initial data on network capacity loadings for the network and servers. Four individuals were selected to use the HDS and NCD systems to connect with PowerBuilder, a database software development tool, running on the Intrigue server. In this mode the NCs play the role of a terminal sharing the computational capacity of a server.

Desktop Computing Architectures

The basic variations among four desktop computing architectures (traditional PCs, NetPCs, and the two NCs) are shown in table 5 and discussed in further detail below.

Traditional PC–Fat Client. The traditional desktop PC is one that has a fast processor (Pentium or PowerPC), ample memory (>24 MB), local storage, and removable media (floppy and CD ROM). It is a self-contained system in which all operating system code, applications, and data reside on the local disk and execute on the local processor. Mail and web services are the only services that require server access. Most administration must be done at the system. It is also important to note that the traditional PC has the widest variety of vendors and choices. From a price and innovation standpoint this is good, but from an overall administration standpoint this is a nightmare which is directly responsible for the high cost of ownership and decrease of productivity in core functions.

NetPC–Fat Client. The NetPC is an invention of Microsoft and Intel. It is basically a locked-down PC with the promise of greatly reduced management costs.

These systems are being designed with the following features to reduce the administration costs:

- Remote power management
- Automatic system update and application installation
- All state information kept on server
- Central administration and system lock-down features

The operating system code, applications, and data reside on the local disk and execute on the local processor. The system itself is physically more secure to prevent nonprofessional tampering with the configuration. This is to reduce the “futz factor.”

Network Computer. The NC is defined in the NCRP, http://www.nc.ihost.com/nc_ref_profile.html. This profile was developed by a collaboration between Apple, IBM, Netscape, Oracle, and Sun Microsystems in July 1996.

The NCRP is intended to provide a common denominator of popular and widely used features and functions across a broad range of scaleable network computing devices, including PCs. The hardware guidelines cover a minimum screen resolution of 640 × 480 (VGA) or equivalent, a pointing device (mouse or track ball), text input capabilities, and audio output. The agreed upon Internet protocols are transmission control protocol (TCP), file transfer protocol (FTP), optional support of network file system to enable low-cost, medialess devices while allowing for persistent storage in the network; and SNMP, a protocol enabling the distributed management of devices.

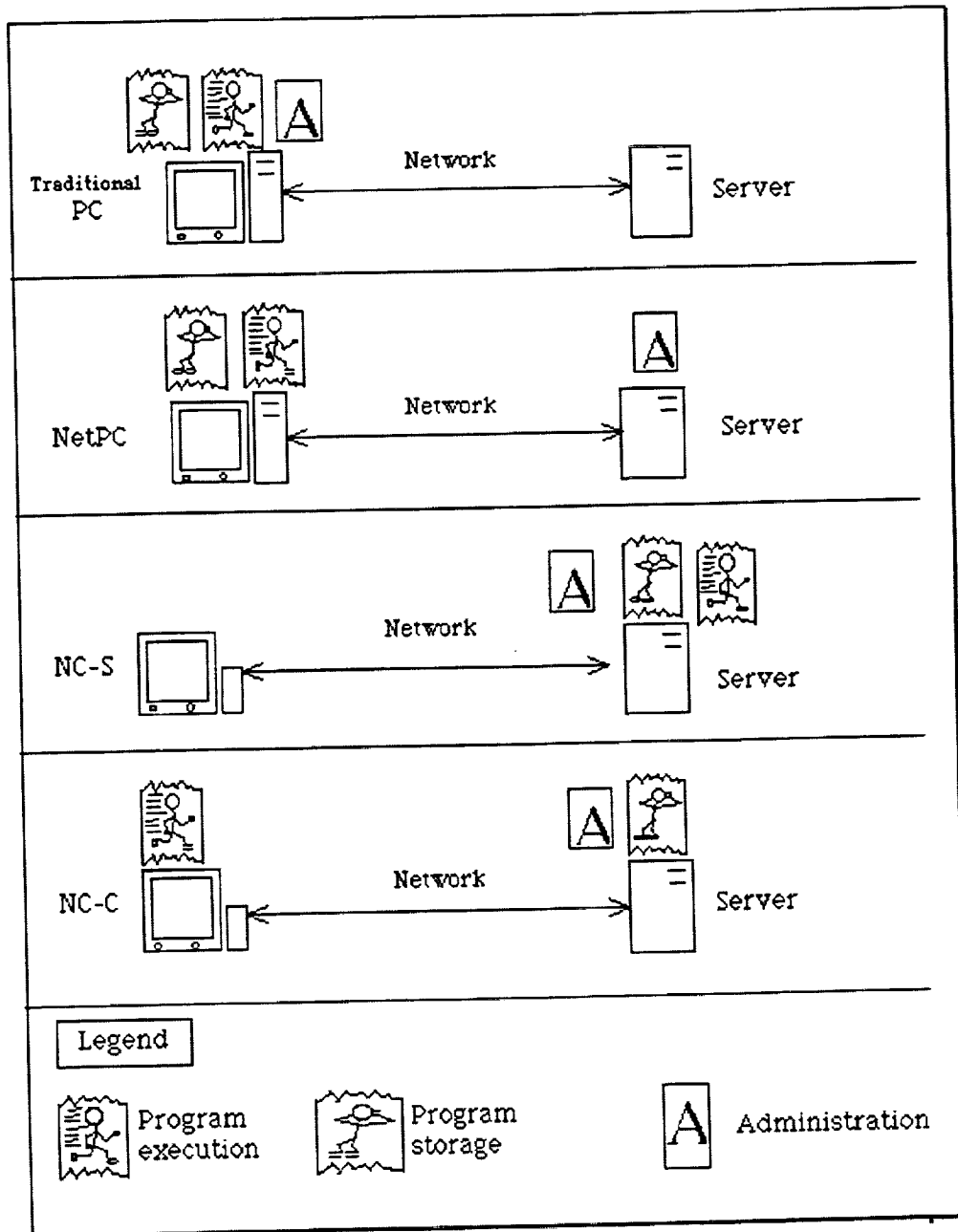
The profile further adheres to web standards HTML, HTTP, and the Java application environment, as well as to mainstream mail protocols (SMTP, IMAP4, POP3) and common data formats such as JPEG, GIF, WAV, and AU. Optional security features are supported through emerging security application program interfaces; security standards are ISO 7816 SmartCards and the EMV (Europay/MasterCard/Visa) specification. The vendors have responded by offering products which fall into the two general groups referred to as NC-S and NC-C.

NC-S (Citrix Winframe)–Thin Client. NC-S is the Windows/PC equivalent to the UNIX/X-terminal model. Specially modified Windows NT* servers provide remote multi-user interface capability. The client system is usually a diskless display terminal

Table 5. Desktop computing architecture summary

	PC	NetPC	NC-S	NC-C
Local storage	Yes	Yes	No*	No*
Memory requirement	>16 MB	>16 MB	<16 MB*	<16 MB
User state location	Local	Local/Server	Server	Server
Applications storage location	Local	Local	Server	Server
Removable storage (floppy)	Yes	Yes	No*	No
Requires network and server to operate	No	No	Yes	Yes
Application execution location	Local	Local	Server	Local

*Exception is HDS @workstation, optional PCMCIA hard disk available, local browser, and applications; also local floppy drive.



much like the X-terminal. All applications code is executed on the server and all applications code and files stay resident on the server. Many of these products precede the creation of the NCRP and are simply adding on Java capability. The major advantage of this product group is the seamless ability to run Microsoft Office applications on an NT server.

NC-C (Java)-Thin Client. NC-C is the pure Java approach to network computing. This architecture is not built on any legacy technology such as X-terminal technology. The NC-C systems are designed for execution of Java code. Sun Microsystems is the main champion of this approach with its Java stations. Java applications are stored on a network server. NC-C (Java) clients download the needed Java code from the server and do local execution. If additional functions are needed by the application, then this code is downloaded on demand to the client. Although this approach

most closely meets the intended goals of the NCRP, it also has the following drawbacks:

- Porting of existing applications to Java is in its infancy
- Java language is still in development
- Access to other services and functions not ported to Java must be done through Java gateway applications

It is important to note that even though NCs are being designed to meet the open standards of the NCRP, there are substantial differences in how they are booted and managed. This means that for the immediate future the choice of NC boot and management servers is very limited, usually to a product from the same manufacturer as the NC (see the Maturity, Development, and Growth of NCT section of this report).

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